Background material for presentation on Bioenergetics and Juvenile Growth

Within the Recruitment Processes Alliance (RPA), projects are aimed at gaining a better understanding of species' ecology and how early life stages respond to their environment (and environmental change). All projects are geared towards understanding mechanistic links and are couched in understanding fluctuations in recruitment success in order to inform stock assessment and assist assessment managers.

Status of ecosystem data (TOR 4)

Much of the data and information regarding bioenergetics of juvenile groundfish comes from the late-summer BASIS survey, which is conducted over the eastern Bering Sea (EBS) shelf. This survey was predominantly a surface-trawl survey with acoustics and targeted midwater tows beginning in 2010; in 2015, oblique tows were conducted. Additional information about the ecology and bioenergetics of age-0 flatfishes comes from a fall Beam Trawl survey that focuses on settlement and nursery areas over the shelf. In 2015, 24-hour sampling allowed additional Beam Trawls to be run. Data are maintained at the AFSC and have been provided to the PARR.

Strategies to obtain and manage ecosystem data (TOR 4)

The RPA is currently investigating several survey redesigns to ensure data collection fulfills ecosystem-related science needs while efficiently sampling across spatial and temporal scales. Survey redesigns are considering different sampling schemes for spring (FOCI) and fall (BASIS) surveys, as well as the benefits of executing surface versus oblique (water-column) tows.

Example 1: Northern rock sole

Age-0 northern rock sole (*Lepidopsetta polyxystra*) preferred nursery habitat is shallow of the 50-m isobaths. When the cold pool (waters <2°C) is not blocking transport (i.e., in warm years) to this preferred nursery habitat, increased recruitment success and survival to age-2 and age-3 occurs. In addition to the presence of the cold pool, juvenile transport is also influenced by the inner front that forms along the 50-m isobath, potentially limiting ingress into the coastal domain (sandy, less than 50 m habitat). Age-0 and age-1 distribution patterns persist until two years later in the bottom trawl survey. In considering survey redesigns, a lack of inshore sampling would prevent further work on shallow water age-0 flatfish species.

Example 2: Pacific cod

Pacific cod (*Gadus macrocephalus*) are found over the shelf in near-surface waters. As they age, they move deeper in the water column and inshore to partially demersal habitat. In spring, larvae are associated with the Alaska Coastal Current waters from the Gulf of Alaska (GOA; via Unimak Pass) and also with nearshore habitat along the Alaska Peninsula. In fall, juveniles were most abundant along the Alaska Peninsula and were more abundant along open coastlines than in embayments (contrary to GOA). Year-class strength may be set during the late-juvenile phase after fish have settled out of the water column. In order to develop and produce recruitment indices, sample redesigns should consider targeting these late-juvenile life stages.

Example 3: Walleye pollock

The spatial distribution of age-0 pollock (*Gadus chalcogrammus*) over the EBS changes with oceanographic conditions over the shelf. In warm years, higher abundances occur in surface waters and fish are distributed broadly across the shelf. In colder year, much lower abundances are observed in surface waters, potentially indicating that the fish were deeper in the water column.

Quantifying the seasonal progression in energy content provides critical information for predicting overwinter survival and recruitment to age-1 because age-0 pollock rely on energy reserves to survive their first winter. Energy densities remain low during the larval phase, consistent with energy allocation to somatic growth and development. Lipid acquisition rates increase rapidly after transformation to the juvenile phase, with energy allocation to lipid storage leading to higher energy densities in late summer. The time after the end of larval development and before the onset of winter represents a short critical period for energy storage in age-0 pollock.

Spatial patterns in prey composition and water temperature lead to areas of enhanced growth, or growth 'hot spots', for juvenile pollock and survival may be enhanced when fish overlap with these areas. A spatial mismatch between juvenile pollock and growth 'hot spots' in 2005 contributed to poor recruitment while a higher degree of overlap in 2010 resulted in improved recruitment. Climate-driven changes in prey quality and composition can impact growth of juvenile pollock, potentially severely affecting recruitment variability.

Energy density, mass, and standard length of age-0 pollock have been measured annually since 2003. Over that period energy density has varied with the thermal regime in the EBS. Between 2003 and 2005 the southeastern Bering Sea experienced warm conditions. Thermal conditions in 2006 were intermediate, and ice retreated much later in the years following 2006 (i.e., cool conditions). Energy density increased from 3.63 kJ/g in 2003 to 5.26 kJ/g in 2010. In contrast, the size (mass or length) of the fish has been less influenced by thermal regime. Relating the average energy content of age-0 pollock to year class strength from the age-structured stock assessment indicates the energetic condition of pollock prior to their first winter predicts their survival to age-3.

In order to progress our understanding of the Bering Sea ecosystem, studies should address both spatial and temporal scales of climate influences. Our ability to sample and interpret changes on short temporal scales to be responsive to climate stanza shifts (i.e., 'warm blob') should be considered during survey redesigns. Further work on groundtruthing predictive models with observational data will help ensure models include the best suite of ecosystem components.

Inclusion of ecosystem data in LMR management advice and how was this inclusion decided? (TOR 6)

Collaborative efforts between RPA scientists, REEM, and the North Pacific Fishery Management Council (i.e., Groundfish Plan Teams) ensures that ecosystem data and predictive indices are conveyed to fisheries management personnel. In 2015, Council presentations included rapid 'impressions' of the ecosystem from current-year surveys to give managers the best suite of information.

Peer-review of ecosystem-related science program and products (TOR 7)

Much of the RPA research from the Bering Sea Project was published in 4 Special Issues of Deep-Sea Research II. Additional peer-reviewed manuscripts, MS and PhD dissertations, and final reports derived from ecosystem-related research are publicly available.

Communication to managers, partners, stakeholders, and the public

Research is communicated in multiple venues, including semi-annual RPA meetings, oral and poster presentations at the Alaska Marine Science Symposium, and the Groundfish Plan Team meetings of the North Pacific Fishery Management Council.